AN OPTICAL SYSTEM OPERATING WITH VARIABLE ANGLE OF INCIDENCE

FIELD OF THE INVENTION

The present invention is generally in the field of optical monitoring/inspection techniques, and relates to a spectrometer method and system.

BACKGROUND OF THE INVENTION

Spectrometer-based techniques, such as spectrophotometry and spectral ellipsometry, are widely used in microelectronics for measuring thin film properties and line profiles. An object to be measured may be a site on a semiconductor wafer (multi-layer stack) that may have with uniform thin-film structure, or may be patterned, e.g., line array in at least one layer of the multi-layer stack. If wavelength of incident light is of the order of the line array period, reflected light is zero-order diffracted light, while higher orders are scattered in different directions and do not reach an optical detector oriented to be capable of detecting the reflected light (scatterometry). For both the specular reflection and zero-order diffraction, the light used for measurements may be polarized. Measurement schemes may be of the kind based on measuring intensity of light (spectrophotometry) or polarization changes (ellipsometry).

An object under measurements, either of uniform or patterned structure may thus be described by an optical model with a set of parameters, such as optical constants, thickness of each layer, pattern geometry and profile. Measurement of a single spectrum is usually incapable of determining more than

two-three unknown parameters of this set with high accuracy and high level of confidence. Hence, if more parameters of the optical model of a measured structure are unknown and are to be simultaneously determined from spectral measurements, more such measurements are to be independently carried out. The known approaches to increase the number of independent measurements (applicable for both the spectrophotometry and ellipsometry) are generally based on the following:

1. Step-by-step removal and measurements of the same stack downward to the substrate layer. Although this approach enables as many independent measurements as needed, it is destructive and is hard to implement for measuring wafers in production.

2. Step-by-step deposition and measurements of the stack layers. This approach provides a required number of measurements, but is timely consuming.

3. Individual deposition of each or some critical layers on a substrate and separate measurements of each of these layers. By this, measurements in a simple single-layer structure allows for determining both the optical properties and thickness of the single layer. The single-layer measured parameters can then be excluded from unknown parameters of the whole stack. This technique is also time consuming, requires a large number of test wafers, and does not takes into consideration the fact that the optical properties of a specific layer may be different when the layer is a part of a multi-layer stack, and therefore does not provide confident information.

4. Applying measurements to the same wafer in different ambiences, e.g., in air and in water, etc. This technique provides more information about the wafer, but a different ambience might cause some chemical changes of the wafer's top layer, such as photoresist.

5. Measurements of the same site on a wafer with different angles of light incidence. **Fig. 1** schematically illustrates such a variable angle measurement

system **10**, for example the H-VASE model commercially available from J.A. Woolam Co., Inc. The system has two arms **12** and **14** mounted for pivotal movement about a pivot axis **16** along a curved frame **18**. The arms **12** and **14** are L-shaped and carry a light source **20** and a detector **22**, respectively. In order to cover the entire surface of a wafer **W**, the latter is supported on a movable X-Y stage **24**, which preferably is also Z-adjustable. This approach provides more information than the single incident angle technique, but suffers from the following drawbacks:

- long measurement time, which while being acceptable for material characterization, is not acceptable for production;
- a measurement system of a large footprint and size, which does not complies with the requirements for a measurement system in production, e.g., integrated metrology system;
- requirement for a massive and rigid mechanical platform, in order to provide accurate changing of the angle of incidence that can hardly be used for integrated metrology.

SUMMARY OF THE INVENTION

There is accordingly a need in the art to facilitate optical measurements in a sample, especially a multi-layer structure, by providing a novel method and system operable with variable angles of illumination and light collection.

The present invention provides for varying the angle of incidence of light onto a specific location (site) on the sample and, optionally also for varying the angle of collection of light returned from this site. The system according to the invention requires neither movement of a light source nor of a light detector, but rather utilizes a light directing assembly having a plurality of deflector elements defining a plurality of incident angles. Interaction of an incident beam with a selected one of the deflector elements provides a selected angle of incidence of

the beam onto the sample. Preferably, the plurality of deflector elements has deflector elements located in a detection channel as well, thereby enabling interaction of the returned beam with a selected deflector element and accordingly a selected angle of light collection by a detector unit.

There is thus provided according to one aspect of the present invention, an optical system for use in measurements in a sample, the system comprising:

(a) a light source operable to produce an incident light beam propagating in a certain direction towards the sample through an illumination channel;
(b) a detector unit for collecting light coming from the sample through a detection channel, and generating data indicative of the collected light;
(c) a light directing assembly operable to direct the incident beam onto a certain location on the sample's plane with a plurality of incident angles, and to direct light returned from the illuminated location to the detector unit, the light directing assembly comprising a plurality of beam deflector elements, at least one of the deflector elements being movable, a position of said at least one movable deflector element defining a selected one of the incident angles.

According to one embodiment of the invention, the plurality of the deflector elements has two arrays of the deflector elements, one array being located in the illumination channel and the other array being located in the detection channel. Each of the arrays may be formed by deflector elements arranged in a spaced-apart relationship along the respective channel, in which case the deflector elements may be planar mirrors with or without associated focusing lenses, at least one of the deflector elements being movable. Each of the arrays may be formed by a reflecting surface of a parabolic-sector mirror, in which case the light directing assembly preferably comprises at least one movable planar mirror in the illumination channel, and preferably also comprises a movable planar mirror in the detection channel. According to another

embodiment of the invention, the plurality of deflector elements comprises a single parabolic-sector mirror that faces the sample's plane with its reflecting surface. In this case, the light directing assembly comprises planar mirrors, at least one being movable between a plurality of operative positions thereby defining the plurality of the incident angles.

According to another aspect of the present invention, there is provided, a method for measuring in a sample, the method comprising:

(i) providing an incident light beam propagating in a certain direction towards the sample along an illumination channel;

(ii) directing the incident beam onto a certain location on the sample's plane with a plurality of incident angles, said directing comprising deflecting the incident beam by a selected one of a plurality of deflector elements resulting in the selected one of the angles of incidence of the beam onto said certain location.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic illustration of the prior art multi-angle optical system;

Fig. 2 is a schematic illustration of an optical system according to one embodiment of the invention;

Figs. 3A to 3D more specifically illustrate three possible examples, respectively, of a deflection element suitable to be used in the optical system of Fig. 2;

Fig. 4 schematically illustrates an optical system according to another embodiment of the invention;

Fig. 5 is a schematic illustration of an optical system according to yet another embodiment of the invention, utilizing the multi-angle illumination/detection and also normal-incidence illumination/detection and/or imaging;

Figs. 6A and 6B illustrate two more examples of using normal-incidence illumination/detection or imaging channel in the optical system of the invention;

Figs. 7A and 7B illustrate optical systems according to yet another examples of the invention designed for carrying out multi-angle and normal incidence measurement/monitoring, as well as imaging and auto-focusing functions;

Fig. 8 is a schematic illustration of yet another embodiment of the invention, wherein a deflector assembly comprises a parabolic-sector mirror; and

Fig. 9 illustrates how the system of the present invention can be used for measuring diffraction efficiency for the first (negative) diffraction order additionally to zero order standard measurements.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 shows the prior art optical system capable of providing various angles of incidence of a light beam onto a sample.

Referring to **Fig. 2**, there is illustrated an optical system **100** according to one embodiment of the invention applied to a sample (e.g., wafer) **S**. The system **100** comprises such main constructional parts as a light source **102** (e.g., a Xe lamp) producing an incident light beam **B**, which in the present example propagates from the light source parallel to an axis **OA** normal to the sample's plane; a detector unit **104** (e.g., spectrophotometer); and a light directing assembly, generally at **106**, comprising a plurality of deflector elements. Light beam **B** propagates through an illumination channel **IC**, impinges onto the sample at a location **L**, and returned light **B'** (reflected and/or scattered)

propagates through a detection channel **DC** towards the detector **104**. The sample is typically supported on a stage, and in order to measure/monitor a plurality of sample's sites a relative displacement between the sample and the optical system (at least deflector assembly) is provided, preferably by moving the stage with respect to the optical system. The stage may be of different types, i.e., x,y- or r,θ-movable stage for scanning the entire surface of the wafer, and z-movable for bringing the measurement site to the best focus of the optical system.

In the present example of Fig. 2, the plurality of deflector elements in the light directing assembly **106** has two arrays of deflector elements **108** and **110** located at both sides of the axis **OA**. The array **108** is associated with the light source **102** (illumination channel **IC**) and the array **110** is associated with the detector unit **104** (detection channel **DC**). Additionally, in the present example of Fig. 2, each of the arrays **108** and **110** has separate (discrete) deflector elements – four such elements **108A-108D** and **110A-110D** in the arrays **108** and **110**, respectively, which are arranged in a spaced-apart relationship within the respective channel. All the deflector elements, except for the lowermost ones (closest to the sample's plane) **108D** and **110D**, are movable to be in and out of the optical path of the respective beam (incident or returned), e.g., are mounted for a reciprocating movement along X- or Y-axis. Generally speaking, each beam deflector element in the array can be in its operative state, in which it is in the path of the respective light beam, and can be in its inoperative state, in which it is out of the path of the respective beam. This can be implemented in different ways, namely, by reciprocating, rotating or pivotal movement of the element with respect to the path of the light beam propagation towards the element. When the selected one of the deflector elements is in the optical path of the light beam, all other elements are out of this path. For example, the deflector elements can be sequentially shifted between the two positions. This can be realized by locating the uppermost deflector element **108A** in the path of the emitted beam **B**, thereby

automatically preventing the beam interaction with the other elements **108B-108D**, and providing the beam incidence onto the location **L** on the sample with a certain incident angle θ_1. In this case, the deflector elements **110A-110D** of the detection channel are arranged such that the deflector element **110A** only is in the path of the specularly reflected beam **B'**. Then, the uppermost element **108A** is shifted away from the axis **OA**, thereby automatically providing the incident beam deflection by the next element **108B**, etc. It should be understood that in order to provide the operative state of a selected deflector element, not necessarily this selected element is to be moved, but rather one or more other elements of the deflector assembly, as will be exemplified further below.

As shown in Fig. 2, the incident beam interaction with a different one of the deflector elements **108A-108D** results in a different angle of incidence of the beam **B** onto the same location (point) **L** on the sample. To this end, the deflector elements are differently oriented with respect to the axis **OA**. In the example of Fig. 2, variation of the angle of light collection (detection) is aimed at collecting only specular reflections of the incident beam. It should also be noted that the movable elements of the illumination and detection channels forming a pair with respect to the certain incident/collected angle, e.g., elements **108A** and **110A**, can be associated with a common drive.

The number of different angles of incidence/collection depends on the opto-mechanical design of the system **100**. Practically, the provision of four-five angles is sufficient for most of the inspection/monitoring applications, enabling the system (including both the illumination and the detection channels) to be compact, up to the wafer size (200-300mm).

Since each deflector element in the arrays of the illumination and detection channels can be separately aligned, a very high accuracy of alignment can be achieved, which enables to provide accurate location of the illumination spot (location **L**) on the chosen measurement site. During the alignment

procedure, a nominal angle of incidence may be changed within a certain tolerance. However, accurate measurements require knowledge of each angle of incidence with high accuracy. This problem can be solved by using a calibration stage. This can for example be implemented in the following way. A known object is measured, e.g., SiO_2 layer on Si with the known thicknesses (commercially available from VLSI Standards Inc), and the actual angle of incidence is calculated by reaching the best fit between measured value of the film thickness in calibration standard parameters and its specified value.

It is typically desirable to set a measurement spot on the same place (x, y, z) on the wafer for all the angles of incidence, which is practically difficult to implement with the currently available alignment technique. To solve this problem, the coordinates (x, y, z) of the measurement spot may be determined for each incident angle separately by carrying out another calibration procedure. A calibration target in the form of a small mirror, e.g., chrome-on-glass mirror of a 50μm diameter may be used. By changing x, y and z coordinates of the wafer supporting stage, a maximal signal of the returned light (reflection) is determined for each incident angle. This correction of coordinates (Δx, Δy and Δz) is stored in the memory of the measurement system (a control unit). Thus, while changing the angle of incidence/collection by selecting a corresponding pair of the deflector elements, the position of the wafer stage is changed accordingly to compensate for Δx, Δy and Δz for this specific angle.

Reference is now made to **Figs. 3A-3D** showing several examples of the configuration of the separate deflector elements suitable to be used in the system **100**. In the example of Fig. 3A, the deflector element **208** has a planar reflecting surface (mirror), which may be associated with a lens **209** for beam focusing purposes, as shown in Fig. 3B. In the example of Fig. 3C, a deflector element **308** has a curved (concave) reflecting surface (preferably, a parabolic mirror) thereby

providing both the deflection and focusing of the incident beam. As shown in Fig. 3D, a deflector assembly part **408** (associated with either illumination or detection channel) can be formed with discrete deflector elements **408A-408D** supported in a step-like structure, so as to be moved together by a common drive (not shown). It should be noted that the deflector elements used in arrays of the illumination and detection channels are not necessarily of the same type, but may be of different types. For example, the illumination channel may include the curved mirrors, while the detection channel may include planar mirrors.

Fig. 4 illustrates an optical system **500** according to another embodiment of the invention. To facilitate understanding, the same reference numbers are used for identifying components that are common in systems **100** and **500**. In the system **500**, the plurality of deflector elements in a light directing assembly **506** includes two symmetrical sectors **508** and **510** of a parabolic mirror accommodated in, respectively, illumination and detection channels and oriented such that the measurement site (location **L**) is located in the focal point of the mirror. Further provided in the light directing assembly **506** is a pair of movable planar mirrors **512** and **514** located in, respectively, illumination and detection channels **IC** and **DC**. In the present example, in distinction to the previously described ones, each of the continuous parabolic reflecting surfaces of the mirror sectors **508** and **510** presents an array of deflector elements (deflecting locations), providing a plurality of different angles of incidence/collection. In order to select a desired one of the incident angles, the mirror **512** is moved along the X-axis into a corresponding position with respect to the mirror sector **508**. Similarly, in order to collect light returned from the sample with a desired angle (e.g., specular reflection), the mirror **514** is brought to a corresponding position along the X-axis. It should be understood that the provision of a continuous parabolic surface allows for obtaining the light response intensity (e.g., specular reflection) as a continuous function of angle of incidence.

In the systems **100** (Fig. 2) and **500** (Fig. 4), multiple, non-zero angles of incidence of the beam onto the sample are utilized. **Fig. 5** schematically illustrates how such a system can be easily modified in order to provide also measurement/monitoring of the sample with the normal incidence (zero-angle). A system **600** is shown having a light source **602**, a detector unit **604**, and a light directing assembly **606** comprising the plurality of deflector elements (including two arrays of deflector elements **608** and **610** in the present example), mirrors **612**, **614** and **616**, and a beam splitter **618**. The detector unit **604** has a spectroscopic detector **605** and a tube lens **622**. Optionally provided in the system **600** are polarizing elements **620** and **621** located, respectively, in the optical path of a light beam emitted by the light source **602** and a light beam propagating to the detector unit. Mirrors **612** and **616** are mounted for movement (e.g., rotation) between their operative and inoperative states.

When the mirrors **612** and **616** are in the operative state, i.e., in the path of the incident and reflected beams **B** and **B'**, respectively, the multi-angle mode is realized. The beam **B** is reflected by the mirror **612** to propagate through the multi-angle illumination **IC**, thereby resulting in the beam incidence onto the sample with a certain non-zero angle of incidence, and the returned beam **B'** propagates through the multi-angle detection channel **DC** to be reflected by the mirror **616** to the detector unit **604**. By shifting the mirrors **612** and **616** into their inoperative state, i.e., being out of the optical path of the beams **B** and **B'**, the beam **B** is directed towards the beam splitter **618** to propagate through a normal illumination/detection channel **IC'**. The beam splitter **618** reflects the beam **B** to propagate to the sample along the axis **OA** through an objective lens **OL**. A specular reflection $\mathbf{B'_{nor}}$ of the normal incident beam $\mathbf{B_{nor}}$ propagates along the axis **OA** through the beam splitter **618**, and is reflected by the mirror **614** to the detector unit **604**.

It should be understood that the normal incidence illumination/detection channel can utilize separate illuminator and detector, other than those used in the multi-angle illumination/detection system. This is schematically shown in **Figs. 6A and 6B**. In the example of Fig. 6A, an optical system **700A** has a multi-angle illumination/detection sub-system constructed similarly to the system **100** of Fig. 2, and a normal illumination/detection sub-system **701**. The sub-system **701** has a light source **703**, a detector **704**, and a suitable optics including a beam splitter **BS**, an objective lens **OL**, and a tube lens **TL**, and is accommodated such that, in each relative location of the sample relative to the optical system **700A**, the same site **L** is measured/monitored by both sub-systems **100** and **701A**. An optical system **700B** of Fig. 6B, similar to the system **700A**, utilizes the sub-systems **100** and **701**, but with the sub-system **701** being applied to a measurement site $\mathbf{L_1}$ spaced-apart from the site **L** to which the sub-system **100** is applied. In this case, a relative distance between the sites **L** and $\mathbf{L_1}$ is determined in a simple calibration procedure and stored in the system memory.

It should be understood that the normal incidence/detection sub-system **701** can be used as an imaging module, being a microscope with a CCD detector and suitable illumination and imaging optics. A control unit (not shown) of the system thus has an electronic card (frame grabber) for grabbing a video signal from the CCD, and an image processing software (including pattern recognition) for processing the grabbed signal. The pattern recognition software allows for identifying the measurement site and, in combined operation with X, Y, Z movable system (stage), allows for localizing the required measurement site in the measurement position (site **L**) as a point of intersection between the axes of the illumination and detection channels.

Reference is made to **Figs. 7A and 7B** illustrating optical systems **800A** and **800B**, respectively, each designed for carrying out multi-angle and normal incidence measurement/monitoring, as well as imaging and auto-focusing

functions. To facilitate understanding, the same reference numbers are used for identifying the similar components in the systems **800A** and **800B**. The systems differ from each other in that the pluralities of deflector elements of the systems **800A** and **800B** comprise, respectively, arrays of separate spaced-apart deflector elements (**808A** and **810A**) and two continuous deflecting surfaces defining the arrays of deflector elements (**808B** and **810B**).

Thus, the system **800A** (and **800B**) comprises a multi-angle and normal-incidence measurement sub-system **801** utilizing a light source **802** (e.g., a Xe lamp with appropriate optics) and a detector unit **804** (e.g. spectrophotometer based on grating and photo-diode array); and an imaging and auto-focusing sub-system **805** utilizing a light source **806** (QTH lamp with appropriate optics) and a detector unit **807** (including a CCD camera). The sub-system **801** further comprises a light directing assembly **809** including the plurality of deflector elements, mirrors **812A** (or **812B** in system **800B**), **814** and **816A** (or **816B** in system **800B**), a beam splitter **818**, and objective and tube lenses **819** and **820**. Preferably, the light directing assembly of the sub-system **801** also comprises polarizing elements **821** and **822**. The detector unit 804 preferably also comprises an aperture stop **823** and a pinhole aperture **824**. The aperture stop **823** is used for adjusting numerical aperture of the reflected light beam. The pinhole aperture **824** is used to limit a measured area on the wafer **W**.

In both systems **800A** and **800B**, each of the mirrors **812A** (or **812B**) and **816A** (or **816B**) is shiftable between its inoperative state (out of the optical path of the respective beam) and operative state (in the path of the respective beam) as described above with reference to Fig. 5. In the system **800A**, at least some of the deflector elements in the arrays **808A** and **810A** are movable to provide operative and inoperative state of the selected deflector element in each array, while in the system **800B**, the parabolic mirrors **808B** and **810B** are stationary mounted, and mirrors **812B** and **816B** are additionally movable along the X-axis between

different operative positions thereof to thereby provide the operative state of the selected deflector element in the arrays (deflecting location).

When the mirrors **812A** and **816A** are in the operative state, a beam **B** from the light source **802** is directed to the sample through the multi-angle illumination channel **IC** (with only one deflector element in the array **808A** being currently operative), and a reflection **B'** of the inclined incident beam **B** propagates through the multi-angle detection channel **DC** to the mirror **816B**, which reflects the beam **B'** to the detector unit **804**. When the mirrors **812A** and **816B** are inoperative, the beam **B** is reflected from the beam splitter **818** to normally impinge onto the same location **L** on the sample, and a reflection $\mathbf{B'_{nor}}$ passes through the beam splitter **818**, and is reflected by the mirror **814** to the detector **804**.

The sub-assembly of the light directing assembly including the beam splitter **818** and mirror **814** is also movable (e.g., along the X- or Y- axis) between its operative and inoperative position to be, respectively, in and output of the optical path of the respective beams. When this sub-assembly is operative, the system **800A** functions as described above, namely, carries out measurements with the sub-system **801**. In order to operate the sub-system **805** to carry out pattern recognition and/or auto-focusing, the sub-assembly **818-814** is shifted into its inoperative state.

The sub-system **805** comprises a grid assembly **825**, a beam splitter **826** for spatially separating incident and reflected beams $\mathbf{B_{inc}}$ and $\mathbf{B_{ref}}$, and a tube lens **827**. There are several ways to reach the best focus. As shown in the figure, beam $\mathbf{B_{inc}}$ passes through the grid assembly **825**, is reflected by the beam splitter **826**, and is focused onto the sample by the tube lens **827** and the objective lens **819**. The reflected beam $\mathbf{B_{ref}}$ propagates back to the CCD **804** through the beam splitter **826**. The use of the grid assembly **825** is aimed at finding the best focus by analyzing the image of line arrays (grid) projected on the sample plane

through the illumination channel. This technique is disclosed in U.S. Patent No. 5,604,344 assigned to the assignee of the present application. Generally, another auto-focusing sensors may be applied as well.

Turning now to **Fig. 8**, there is illustrated yet another embodiment of an optical system **900** according to the invention. The system **900** comprises a light source **902** optionally associated with a polarizing element **903**; a detector unit **904** (e.g., including a spectrophotometer) also optionally associated with a polarizing element **905**; and a light directing assembly **906**. The light directing assembly **906** comprises a double-side movable planar mirror **908**, a wavelength-selective beam combiner **910** (e.g., transparent for wavelength more than 750nm and reflective for wavelengths up to 750nm), three planar mirrors **912, 914** and **916**, and a parabolic-sector mirror **918** whose continuous reflecting surface facing the sample's plane presents a plurality of deflector elements. The mirror **918** is formed with an opening **918A** (generally, an optical window), where for example an objective lens **919** can be located. The provision of the optical window enables a normal incidence illumination/detection. The wavelength selectivity of the mirror **910** is optional and is associated with the provision of an imaging channel formed by an additional light source **920**, an imaging detector unit **922** (e.g., CCD camera), a beam splitter **924** and a tube lens **925**. It should be noted that the use of the additional light source **920** is optional, and the same light source **902** can be used in the imaging channel, in which case the mirror **908** is shifted into its extreme left position denoted **908'**. Further provided in the light directing assembly is a beam splitter **926** serving for the normal incidence measurement, as well as for imaging purposes in this specific configuration. A grid assembly **927** is appropriately accommodated in front of the light source **920** for auto-focusing purposes.

It should be noted that the double-side movable planar mirror **908** can be replaced by two single-side planar movable mirrors. The dimensions of the

mirror **908** (thickness and length) are defined by the predetermined plurality of incident angles, as well as by the configuration of the optical scheme, including dimensions of the beam splitter **926**, etc.

The system **900** operates in the following manner. In the multi-angle illumination/detection mode, mirrors **908, 910, 912, 914** serve for sequential reflection of a light beam **B** emitted by the light source **902** towards the mirror **918**. The position of the mirror **908** along the X-axis defines the deflector element (deflecting location) on the continuous reflecting surface of the mirror **918** on which the light beam **B** would impinge, and therefore defines the angle of incidence of the beam **B** onto the location **L** on the sample **S**. In the normal-incidence mode, the mirror **908** is in its extreme position **908'**, and the beam **B** is sequentially reflected by mirrors **908'** and **910**, and is then reflected by the beam splitter **926** to propagate through the opening **918A** to the location **L** on the sample. The normally reflected beam would propagate back through the beam splitter **926** towards the detector unit **904**. In the imaging mode, beam **B"** produced by the light source **920** is reflected from the beam splitter **924** and transmitted by the wavelength-selective mirror **910** to be further reflected from the beam splitter **926** towards the location **L** along the axis perpendicular to the sample's plane. A normally reflected imaging beam propagates back and is reflected by the beam splitter **926** to the CCD **922**.

As indicated above, an imaging channel may be combined with a normal incidence illumination/detection channel. This allows for combining spectral measurements at both normal and oblique illumination in the single measurement system. In the case of spectrometry, this also allows, in some cases, for measuring diffraction efficiency for the first (negative) diffraction order additionally to zero order standard measurements. A schematic beam propagation scheme is schematically illustrated in Fig. **9**. The patterned sample **S** has a grid **G** (line array). An illuminating beam **B** impinges onto the grid

with a certain non-zero angle of incidence, and the first negative diffraction order $\mathbf{B_1}$, angle ($-\varphi$), and a zero-order beam $\mathbf{B_2}$ (specular reflection) can be detected. A relative angular position (φ) can be detected for each wavelength of incident light, as follows: $2d\sin(\varphi)=m\lambda$, wherein d is the period of grid, λ is the wavelength and m is integer corresponding to the diffraction order number.

It is thus evident that the present invention provides a simple construction of an optical system having a deflector assembly with at least one movable element capable of providing variable angles of incidence and light collection with stationary mounted light source and detector. The system can be easily adjusted for additionally illuminating the same location (site) of the sample with a normal incident beam, as well as for imaging the same site.

Data indicative of the detected light is received at a control unit having a suitable data processing utility, which is operable to analyze the received data and determine at least one of the following sample's parameters: reflectivity R as a function of wavelengths or angle of incidence or both; diffraction efficiency as a function of wavelength at zero order diffraction; and typically ellipsometry measured parameters as Δ, which is a change in phase of the reflected beam from the incident beam, and ψ, which is defined as the arctangent of the amplitude ratio of the incident and reflected beams.

Those skilled in the art will readily appreciate that various modifications and changes can be applied to the embodiments of the invention is hereinbefore exemplified without departing from its scope defined in and by the appended claims